1. PUBLISHABLE SUMMARY

ICT-eMuCo (www.emuco.eu) is a European project with a total budget of 4.6M€ which is supported by the European Union under the Seventh Framework Programme (FP7) for research and technological development with 2.9M€. This project is coordinated by Ruhr-Universität Bochum, which is known as one of the biggest universities in Germany. The strong academic and industrial partners Technische Universität Dresden (Germany), University of York (United Kingdom), "Politehnica" University of Timisoara (Romania), Infineon (Germany), Telelogic (Sweden), ARM (United Kingdom) and GWT-TUD (Germany) are also in the consortium.

Mobile communication has become the dominant branch in the communication business over the last decade and is still rapidly growing in market. The fast growing feature set of mobile handsets positions the devices, originally only built for communication, in the domain of consumer electronics (CE). This convergence is already leading to a decline of the mobile handheld PDA market. Even more, no other consumer electronic device has been sold more often than the mobile handset making it the “Queen of consumer electronics”. Mobile devices for systems like the Universal Mobile Telecommunication System (UMTS) and the future Long Term Evolution (LTE) incorporate multiple wireless connectivity standards to provide the best quality of service in the current environment of the user, with a future vision of an IP based network.

In order to make these new services possible, data transmission rates for mobile devices are growing rapidly as we move from third-generation to beyond 3G wireless access technologies. At the same time, the computational demand for applications will rise, often having to process vast amounts of (multimedia) data. The traditional approach of increasing computational power by steadily accelerating the processor clocks cannot be pursued further. The amount of additional power consumption required would be prohibitive for mobile devices with battery capacity constraints and limited heat dissipation. Thus, future mobile computing platforms for handsets face a dramatic contradiction of increasing requirements on computational resources, while keeping the power consumption at current levels (or even decreasing to reduce physical size). Another aspect is the dramatic increase of multimedia applications in the broadest sense, including video streaming, video conferencing, complex graphics etc. together with the rise of user content driven WEB 2.0 applications.

One way out of this dilemma is to distribute the computational load on multiple processors. Such architectures allow reduced clock speeds and minimal supply voltages, which in turn provide power-efficiency. This paradigm requires sophisticated multi-core systems and parallelization of software to reach high computational performance. Other key aspects for the embedded communication systems are the requirement of hard real-time operation at least for the modem part of the system, and high levels of required security and reliability. While the protocol stack requires hard real-time operation, the application domain is driven by a great wealth of software already available and a very aggressive development of new applications.

The increasing functionality will also lead to a drastic increase of the crest factor of required computational resources per use case as the difference between the use cases requiring least computational performance and the one requiring most computational performance is increasing, e.g. the difference between a simple text application and one involving video-streaming. A programmable multi-core architecture offers the optimal

solution in terms of power consumption, performance, flexibility and cost. However, today's handset architectures are not suitable for a multi-core platform.

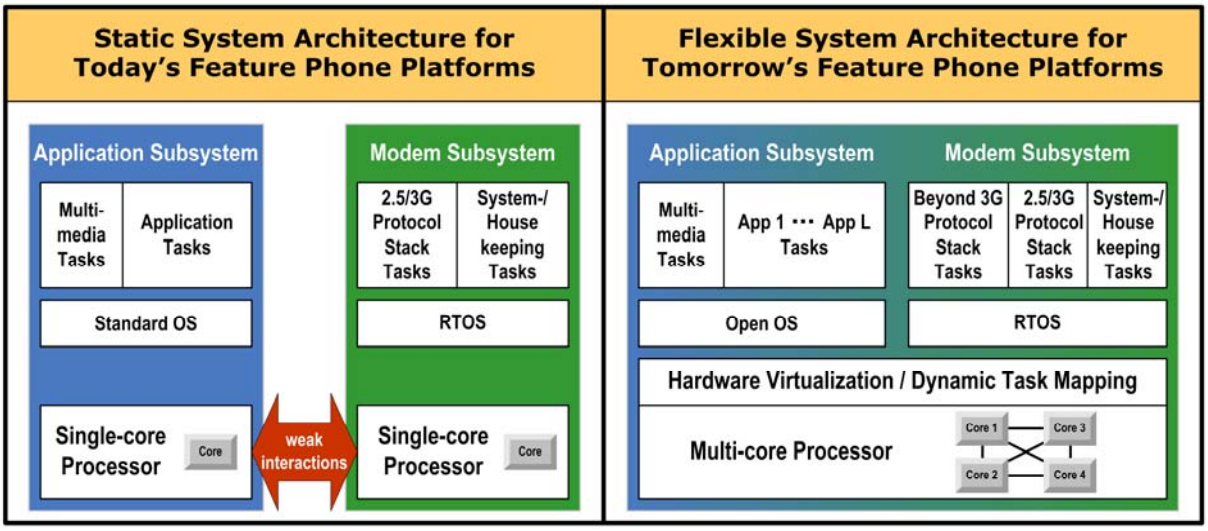

Figure 1: Today's Phone Platforms and ICT-eMuCo's Vision of Tomorrow's Phone Platforms

The functionality of a mobile handset can basically be divided into two categories, the modem and application functionality (cf. Figure 1, left picture). Both have inherently different requirements on the computational system they use to fulfil their tasks. While the modem functionality is determined by hard real-time operation, the application domain requires high flexibility and extensibility. Today's approach either combines the two on one microcontroller core or separates the domains physically on two or more cores with weak interactions (cf. Figure 1, left picture). The contradiction of exponentially increasing computational performance requirements and low power consumption in combination with high flexibility can be solved by a multi-core approach, homogeneous or heterogeneous.
To optimally exploit the future multi-core architectures for mobile devices a new technology is required which allows a dynamic mapping of the tasks of the modem and application domains to the available cores (cf. Figure 1, right picture) considering both, the domain-specific requirements which are real-time and security on the one hand and openness and security on the other hand. To enable this co-existence of different software environments on multi-core architectures virtualization techniques are used together with the required hardware acceleration to meet the stringent performance and power requirements of embedded systems. The awareness for the existence of multi-cores might also arise at the programmer's level. This is taken care of by a model-driven code generation technology based on SDL for the protocol stack and UML for the application development and modelling.

ICT-eMuCo concentrates on the investigation of the fundamental principles of this approach, i.e.

- the suitability of a multi-core architecture for mobile devices including the power saving mechanisms (through e.g. core "hot-plugging")
- a virtualization approach to abstract the application software layers from the specific implementation of the hardware architecture
- the potential hardware support for an efficient implementation of the virtualization in terms of power and clock cycles
- the required programming paradigms and tool support to efficiently use the multi-core architecture

The final outcome provides the necessary information on the suitability of the multi-core computing system for future mobile devices which definitely will dominate the markets of consumer electronics and therefore are of fundamental importance for the European industries. Maintaining the leadership in these markets also guarantees technology leadership in many areas as e.g. embedded devices, embedded software, semiconductors and System-on-Chip (SoC) development.

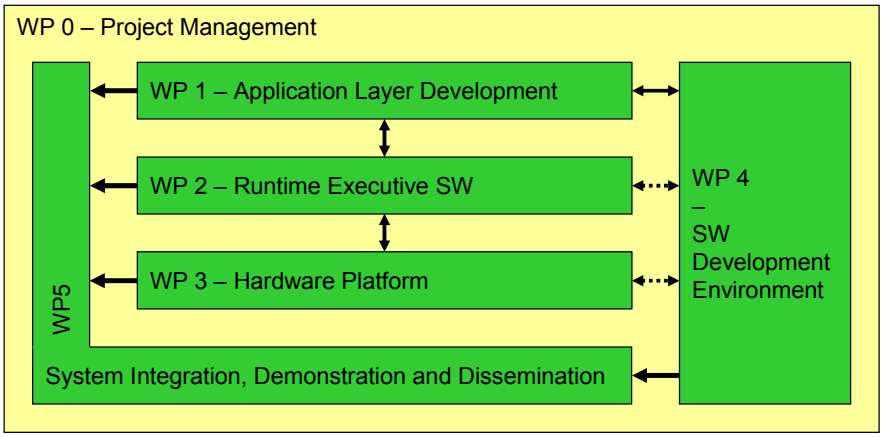

Figure 2: Work Package Structure

The overall main objective of the first reporting period of ICT-eMuCo, from February 2008 to November 2008, is to create a first concept for the HW and SW architectures for a mobile reference platform making use of standard multi-core processors and virtualization technology. Furthermore, a first concept for demonstrating the essential principles of the elaborated concepts is developed. The work packages of the project and their main interactions are shown in Figure 2. The WPs cover all the basic building blocks for a mobile reference platform including the application layer consisting of multimedia example applications and model code for next generation protocol stacks in WP1; the runtime executive software in WP2 based on the microkernel L4; the hardware platform based on ARM multi-core CPUs in WP3, and the software development environment in WP4 based on SDL and UML tooling. The integration of example code for demonstration and exploration purposes is done within WP5 as well as the project dissemination activities.

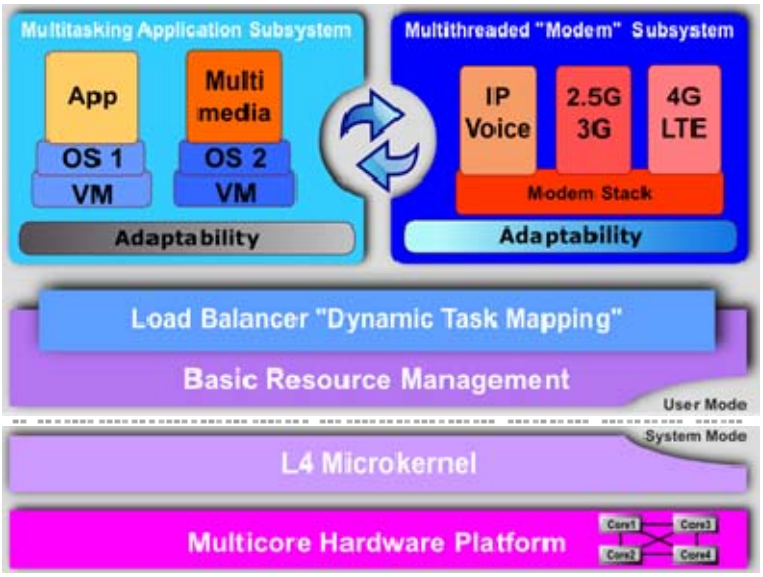

Figure 3: Flexible System Architecture

The requirements analysis is divided into three parts: 1. modem subsystem, 2. application subsystem, 3. load balancer. Nonetheless the application and the modem subsystem have to coexist and the basic resource layer has to provide a flexible framework including a load-balancer to give room for the large dynamics in both domains as indicated in Figure 3.

An LTE protocol stack model was chosen for the requirement analysis and modem software architecture definition. LTE is supposed to succeed the UMTS standard as defined by the ETSI in the 3GPP. Reference code for the layers 2 and 3 was

implemented and ported to the virtual prototype platform as described in WP3, porting to the L4 microkernel is ongoing as well as partitioning for a multi-core system. Also a first benchmarking was done and results will be published soon. As reference multimedia application the IMS framework and the H264 video codec were chosen. The IMS framework is expected to evolve as the de-facto standard for (mobile) multimedia communication and is already well standardised by 3GPP. The implementation of the H264 video codec, also chosen by 3GPP as one of the main codecs, is well suitable for multi-core systems due to its slice approach for frame decoding which naturally map on multiple processing threads.

During the investigations on the overall system architecture the consortium decided to create a new element: the load-balancer module. It is the central component of the project where the “knowledge” about which thread has to run on what core during what time is stored together with the basic thread runtime information. As eMuCo is specific to mobile devices also the inherent system ad-hoc knowledge about its states should be exploited. This could be e.g. the information the protocol stack has about its possible modes and when it has to switch from one mode to another (low data rate, high data rate, paging, …).

The mechanisms to do the load balancing have to be provided by the basic resource layer, i.e. the L4 micro kernel. The primary version of L4 did not support SMP and was extended in the first project phase and now also support the POSIX interfaces and OpenMP as well as thread migration. This has to be tested extensively and eventually adapted to the needs.

Many investigations will be made on the virtual hardware platform first because of limited availability of physical HW for a multi-core platform and second also for its much better flexibility and ease of internal HW state access for analysis and debugging. The HW platform was defined and almost completely implemented in the first reporting period. Also compatibility with existing evaluation boards of the ARM MP chip was assured where applicable increasing SW portability between the virtual prototype and the evaluation HW. However, for some benchmarking it turns out to be very useful to carry out a porting of the L4 microkernel to a full-blown mobile phone platform as the latest Infineon XMM™ 6180 Multimedia Platform Solution and adopt a full product protocol stack as the Infineon Multi Mode Type II Rel. 6 stack to the L4 micro kernel. These activities started with promising progress.

The SW model for the LTE protocol stack was implemented with Telelogic’s SDL tools. The necessary adaptation of the SDL generated code to L4 has already been completed in the first reporting period. As the load balancer needs also to be implemented for investigation of the overall system architecture and also partially for demonstration purposes these efforts shall be placed into WP4. The design and the concepts for the load balancer will be driven by WP1 with contributions from the whole consortium.

Several principles of the eMuCo mobile platform reference architecture will be shown in two demonstrations, one based on the virtual prototype and another based on the ARM MP evaluation board. First concepts and integration plans are developed in WP5.

General information about the project and the consortium is publicly available at the project homepage www.emuco.eu. It includes also press releases, newsletters and other publications to be found in Dissemination as well as an internal area with restricted access.

Contact:
Prof. Dr.-Ing. Attila Bilgic
Coordinator

Ruhr-Universität Bochum
Integrierte Systeme
IC-FO 03/560
Universitätsstrasse 150
D - 44780 Bochum
GERMANY

Phone: +49-(0)234-32 - 29141
Fax: +49-(0)234-32 - 14102
E-mail: attila.bilgic@is.ruhr-uni-bochum.de